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ZERODUR®

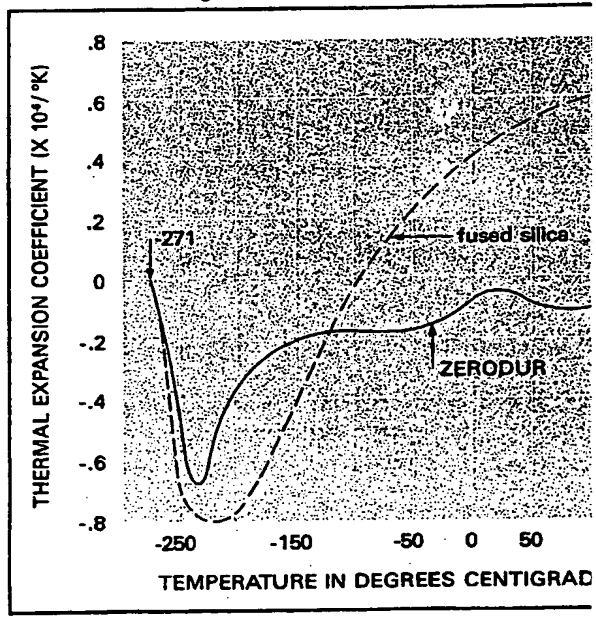
For applications demanding the ultimate in thermal stability and thermal shock resistance, a "zero expansion" material such as Schott ZERODUR® is the best choice. Low expansion glass-ceramics of this type are made by combining a negative thermal expansion coefficient crystalline phase with a positive coefficient amorphous phase in such proportions as to result in an expansion coefficient of almost zero over a large temperature interval. The reason that negative thermal expansion coefficient materials exist is that as temperature varies, so also does the ratio of the energies in vibrational modes which are parallel to or orthogonal to chemical bond directions. This in turn is because of the quantization of vibrational energy levels, and the fact that allowed levels for orthogonal modes need not fall at the same energies. Thus, zero and negative expansion coefficients are large scale manifestations of quantum theory. ZERODUR® contains 70% to 78% crystalline phase by weight. Because of the amount of scattering due to the crystalline content, glass-ceramics such as ZERODUR® are not used for transmissive optics. They are, however, clear enough for visual inspection of bubble and inclusion content.

A reasonable upper bound on the absolute value of the expansion coefficient of low expansion ZERODUR® glass-ceramic at room temperature is $0.15 \times 10^{-6}/°C$. The coefficient can be much smaller, and can have either sign. By design, these materials typically exhibit a change in the sign of the coefficient of linear thermal expansion near room temperature. A comparison of the thermal expansion coefficients of ZERODUR® and fused silica is shown in the graph. As can be seen, ZERODUR® is markedly superior over a large temperature range. ZERODUR® makes ideal mirror substrates for such stringent applications as multiple-exposure holography, holographic interferometry, interferometry generally, manipulation of moderately powerful laser beams, and spaceborne imaging systems.

ZERODUR® CONSTANTS

Density: 2.53 g cm^{-3} at 25 °C
Young's Modulus: 9.1×10^9 dynes/mm^2
Poisson's Ratio: 0.24
Specific Heat at 25 °C: .196 cal/g °C
Coefficient of linear expansion:
(20 °C to 300 °C) = $0.05 \pm .10 \times 10^{-6}$ °C
Abbe Factor: $v_d = 66$

ZERODUR® is a registered trademark of Schott Glass Techn



COMPARISON OF THERMAL EXPANSION CIENTS OF ZERODUR® AND FUSED SILICA.

ZERODUR® mirrors of 1/20 wave flatness are offerred on pages 186 and 187.

SUBSTRATE MATERIALS

We offer a variety of substrate materials, spanning a range of thermal expansion coefficients and hence costs. For applications in which thermal shock is absent and thermal stability is not critical, optical crown glass is a suitable and inexpensive material. For applications involving a moderate risk of thermal shock, pyrex is appropriate. For applications requiring high thermal stability or involving severe thermal shock, synthetic fused silica is a good choice. The respective room temperature coefficients of linear thermal expansion of optical crown, pyrex, and synthetic fused silica are $9 \times 10^{-6}/°C$, and $3.2 \times 10^{-6}/°C$ and $0.5 \times 10^{-6}/°C$. For applications demanding the ultimate in thermal stability and thermal shock resistance, a "zero expansion" glass-ceramic such as Schott ZERODUR® is the best choice.

LOW EXPANSION SUBSTRATE MATERIALS

Some materials may exhibit zero or even negative thermal expansion coefficients over limited temperature intervals. These materials include both crystalline and amorphous substances. The reason for this surprising behavior, for substances of either kind, is that as temperature varies so also does the ratio of the energies of vibrational modes which are parallel to or orthogonal to chemical bond directions. This in turn is because of the quantization of vibrational energy levels, and the fact that allowed levels for orthogonal modes need not fall at the same energies. Thus zero and negative expansion coefficients are large scale manifestations of quantum theory.

Low expansion glass-ceramics combine a negative thermal expansion coefficient crystalline phase with a positive coefficient amorphous phase, in such proportions as to result in an expansion coefficient of almost zero over a large temperature interval. Schott ZERODUR® is such a material. By design these materials typically exhibit a change in the sign of the coefficient of linear thermal expansion near room temperature.

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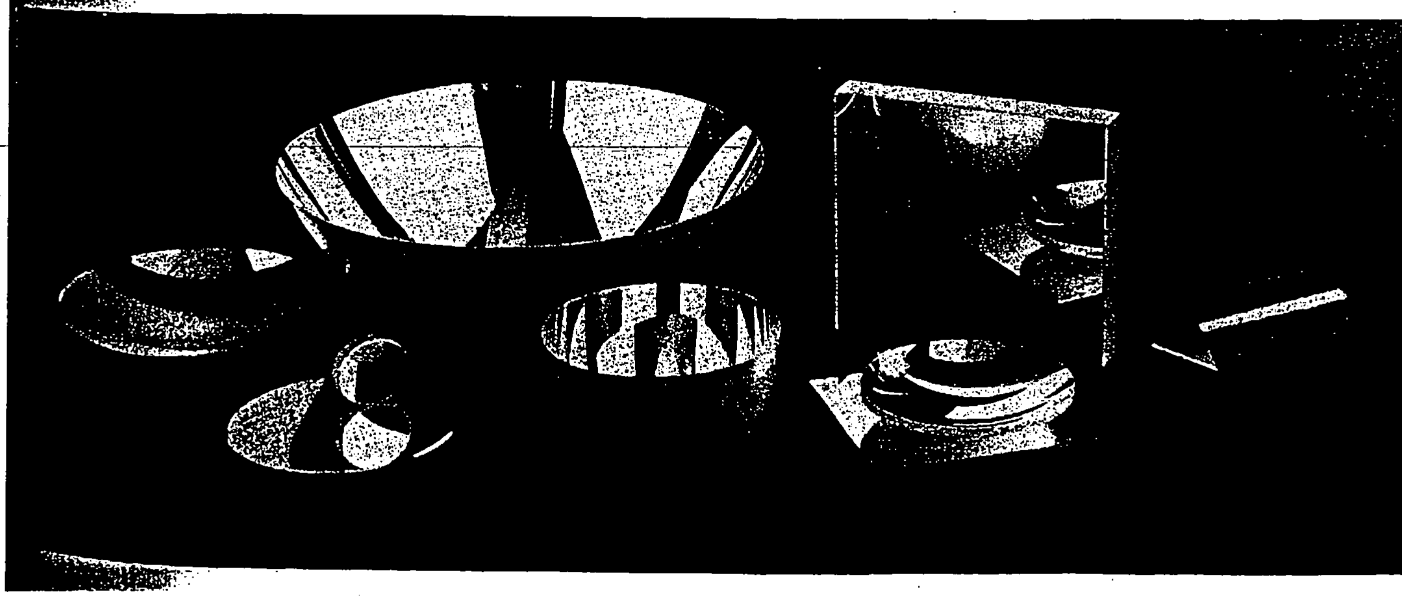
For more information about the materials, see the section on optical materials starting on page 51.



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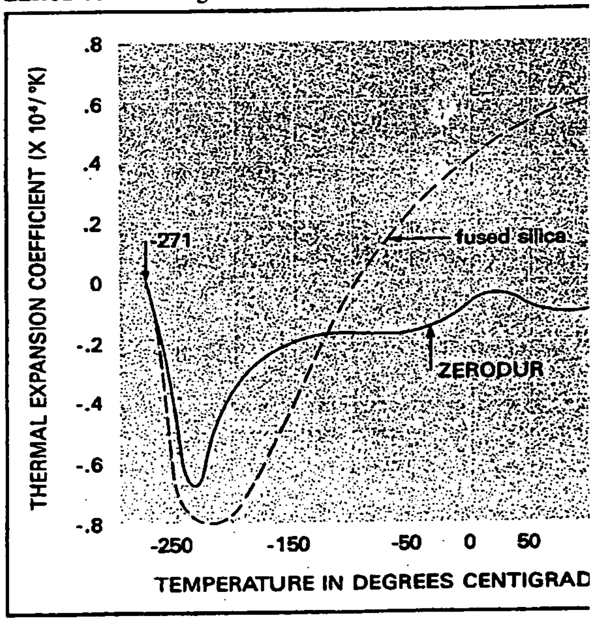

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